November 15, 2016

Japan Pavilion COP22, Marrakech

Evaluations on the emission reduction efforts of Nationally Determined Contributions (NDCs) in cost metrics

Keigo Akimoto

Systems Analysis Group

Research Institute of Innovative Technology for the Earth (RITE)

International Comparison of the Emission Reduction Efforts for the NDCs

How to measure the comparability of efforts

The submitted NDCs include the targets of emissions reduction from different base years, CO_2 intensity, and CO_2 emission reductions from baseline (w/w.o. clear definition of baseline). We need to interpret them through comparable metrics to measure the efforts:

- **Simple metrics (easily measurable and replicable)**
  - Emissions reduction from the same base year

  etc.
- **Advanced metrics (more comprehensive, but require forecasts)**
  - Emission reduction ratios from baseline emissions
  - Emissions per unit of GDP

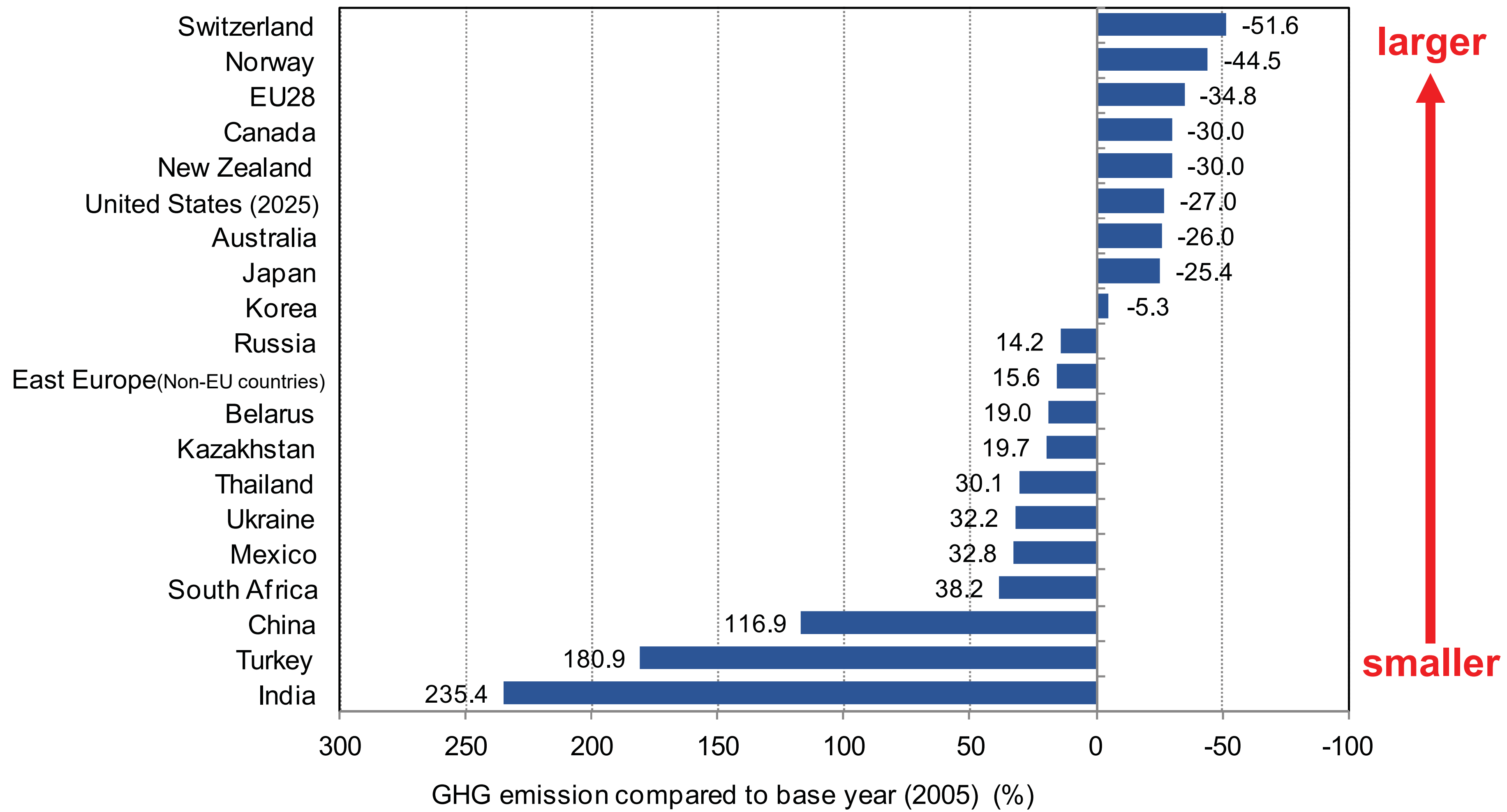
  etc.
- **More advanced metrics (most comprehensive, but require modeling)**
  - Energy price impacts
  - Marginal abatement cost (per ton of CO_2)
  - Abatement costs as a share of GDP

  etc.

Employed indicators for measuring emissions reduction efforts

	Indicators for emissions reduction efforts		Framework	Notes
Simple metrics	**Emissions reduction ratio from base year** (only for OECD countries or Annex I countries)	Compared to 2005	When baseline emissions are expected to stagnate, it is more relevant to simply compare the projected reduction rates (all the more since there are uncertainties regarding the BAU). This is why we use the reduction ratio compared to BAU for OECD countries only - on the other hand, such an approach would be irrelevant for countries where emissions are expected to grow substantially.	Most countries use 2005 as their base year (as a matter of fact, 1990 seems too far in the past to be used as a base year to evaluate the emissions reduction effort for upcoming emissions)
		Compared to 2012 (or 2010)		Adopting a recent base year may enable appropriate comparison of future efforts.
	Emissions per capita (only for non-OECD countries or non-Annex I countries)	Absolute value	For non-OECD countries, we adopt the absolute value of emissions per capita instead of the reduction ratio from base year.	As this indicator (absolute value) is very dependent on country's situations such as economic development stage, industry structure, climate etc., not appropriate to measure reduction efforts.
Advanced metrics	**CO2 intensity (GHG emissions per GDP)**	Absolute value	Reveals what level of CO2 emissions corresponds to what degree of economic activity	It can easily reach bad values for countries with a low GDP; it is also highly dependent on the country's industry structure.
		Improvement rate (compared to 2012 or 2010)	It will be better to measure emission reduction efforts because the bias due to differences in economic growth rate can be removed compared with the indicator of emission reduction ratio from base year.	The value may change greatly for low GDP countries with high GDP growth rate.
	Emissions reduction ratio compared to BAU		The differences in economic growth etc. can be cancelled.	Efforts already made in the past for energy saving etc. are neglected and future abatement potential as well.
More advanced metrics	**CO2 marginal abatement cost (carbon price)**		This is a particularly relevant indicator to assess reduction efforts as it contains countries' differences in terms of economic growth, energy savings efforts, abatement potential of renewables.	Past efforts made for energy saving etc. may lead to high marginal abatement costs for additional reduction efforts.
	Retail prices of energy (electricity, city gas, gasoline, diesel)	Employing historical data of 2012 or 2010 for weighted average	While marginal abatement costs reflect the frontier effort, this indicator corresponds to the efforts made in the baseline as a whole.	Market data is available for ex-post evaluation, but for ex-ante evaluation, only model-based estimates are available which makes uncertainties rather high.
	Emission reduction costs per GDP		This indicator corresponds to the economy's capability to bear efforts for the whole reduction.	Uncertainties are high as this is a model-based estimation.

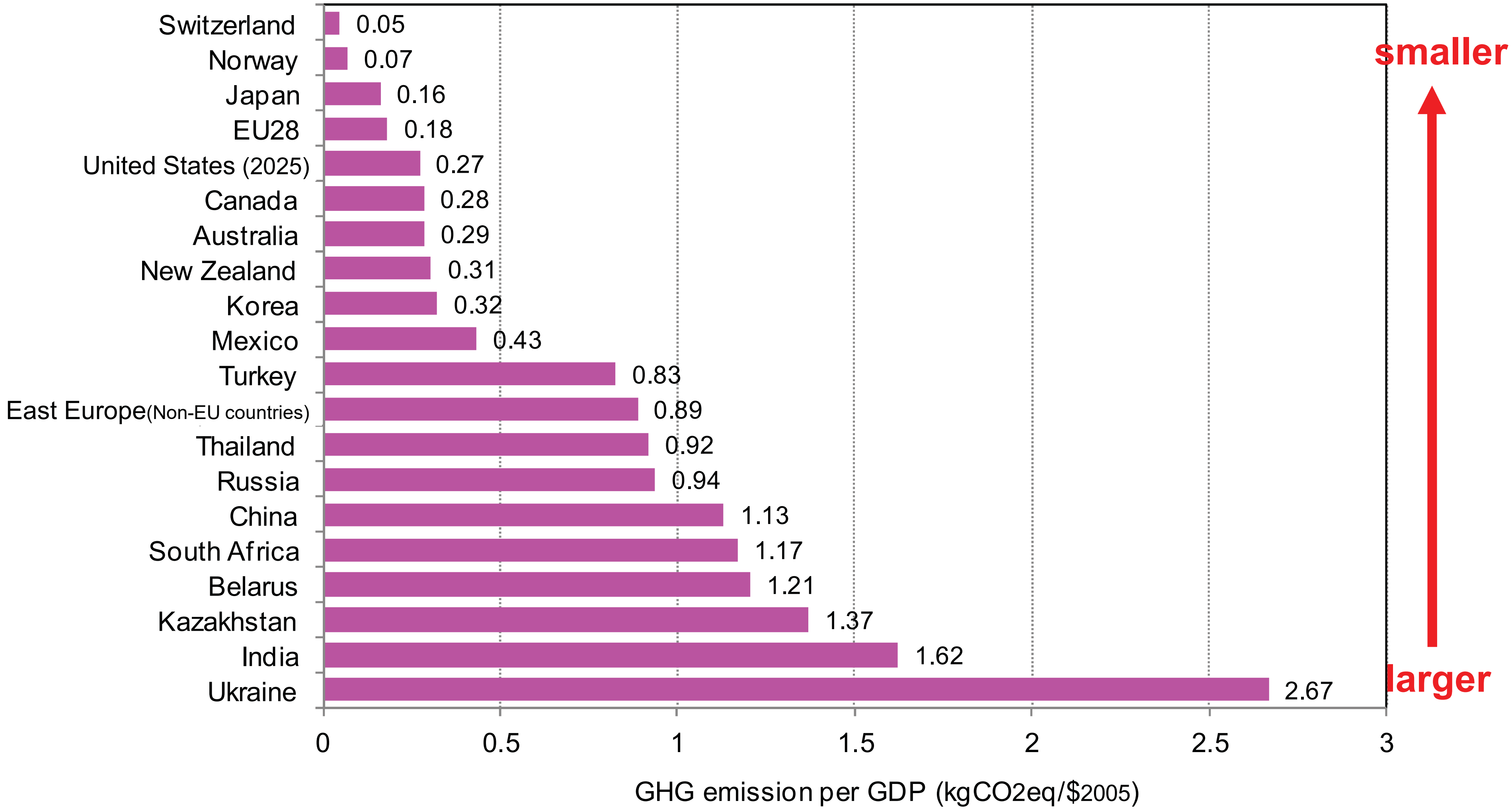
International comparison of emission reduction ratios in 2030 (in 2025 for the U.S.) from the base year of 2005



* The average values are shown for the countries submitted the NDC with the upper and lower ranges.

It is not easy to measure 'emission reduction efforts' by using the emission reduction ratios from a certain base year due to large differences across countries in future economic growth and historical achievements of energy saving and emission reductions, for example.

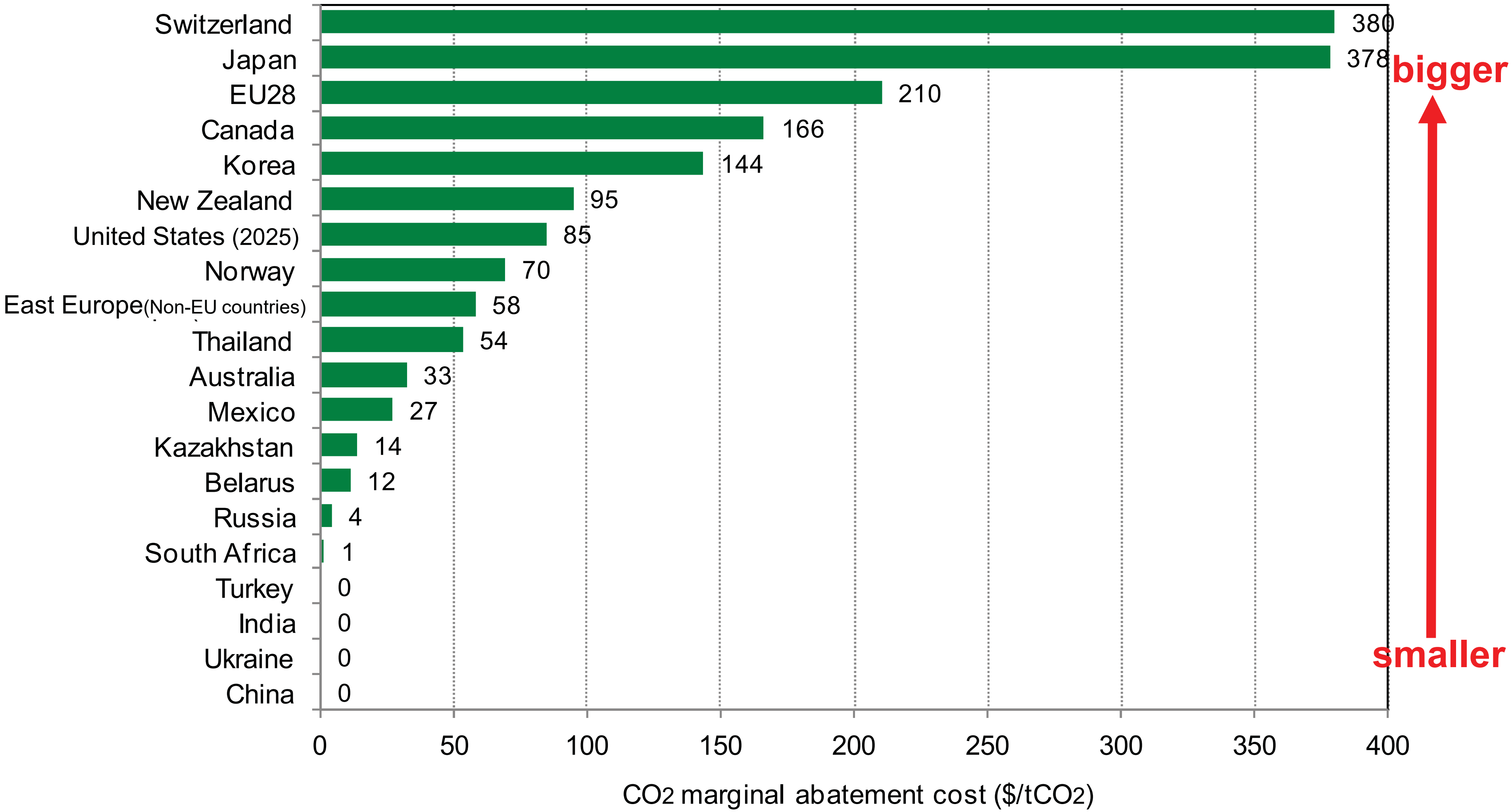
International comparison of GHG emissions per GDP in 2030 (in 2025 for the U.S.)



* The average values are shown for the countries submitted the NDC with the upper and lower ranges.

GHG emission per GDP indicates economic efficiency of GHG emission in general, but it depends on the industrial structures and low-carbon energy supply potentials.

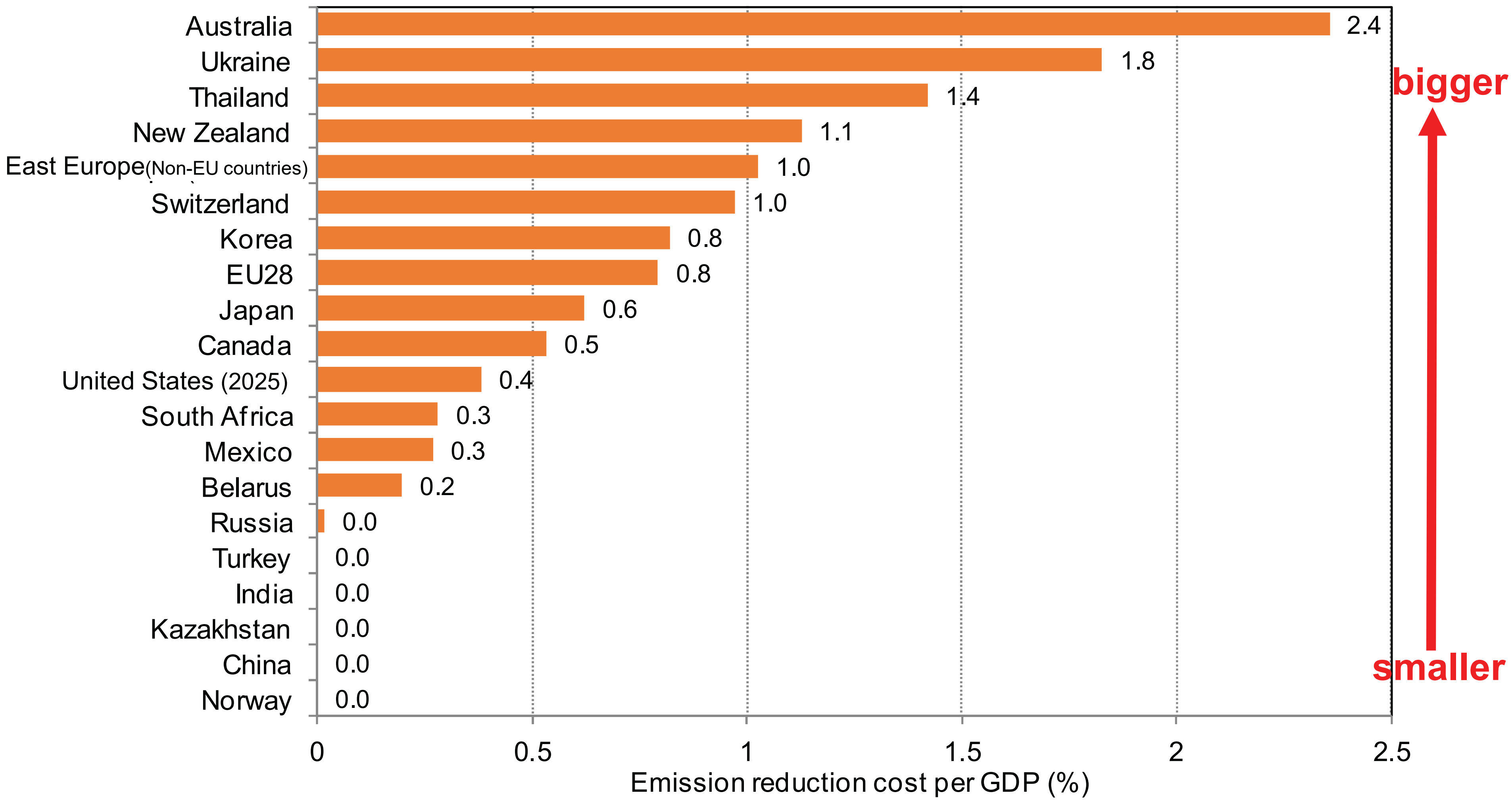
International comparison of CO_2 marginal abatement costs in 2030 (in 2025 for the U.S.) (RITE DNE21+ model)



* The average values are shown for the countries submitted the NDC with the upper and lower ranges.

Large differences in marginal abatement costs are estimated across countries. The large differences raise concern about inducing the carbon leakage and the ineffectiveness of global emission reductions.

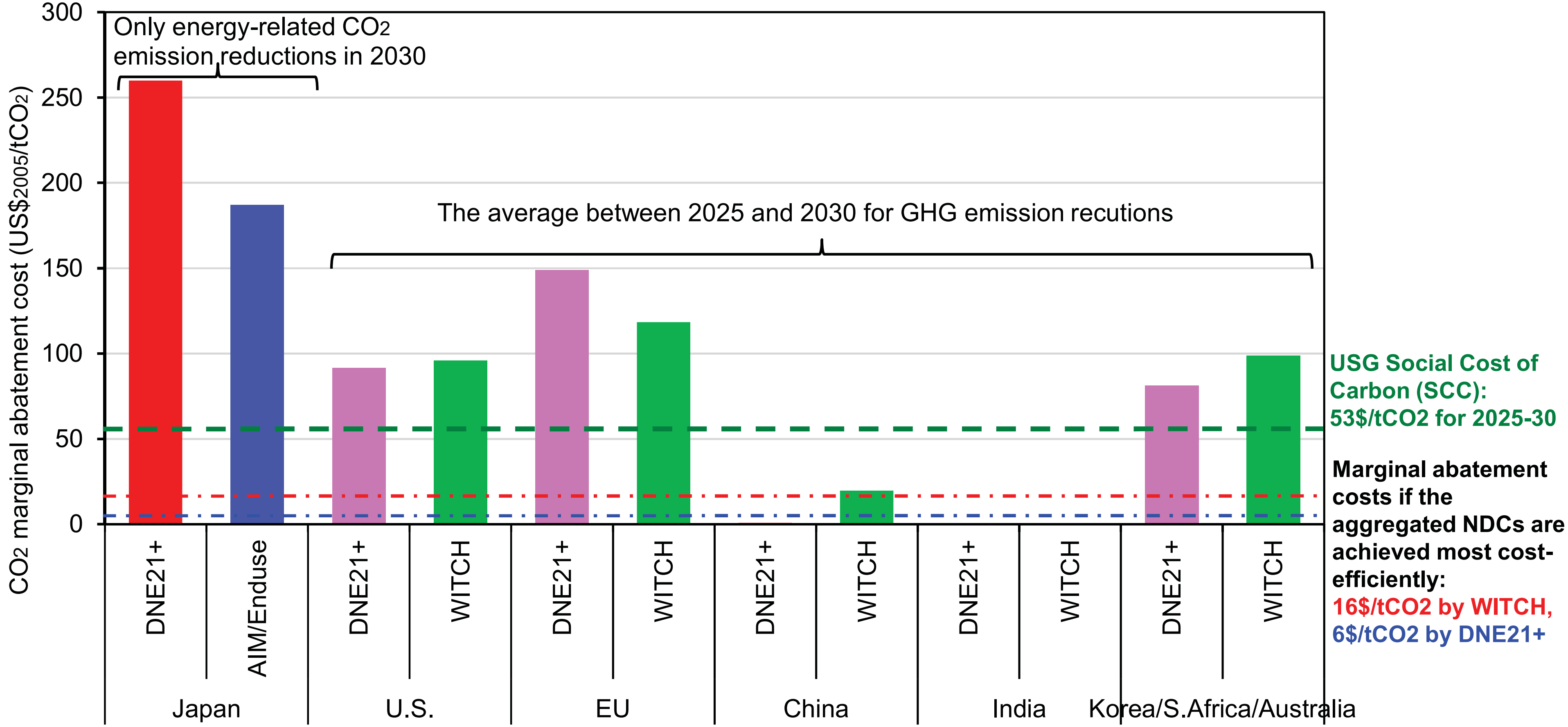
International comparison of emission reduction costs per GDP in 2030 (in 2025 for the U.S.) (RITE DNE21+ model)



* The average values are shown for the countries submitted the NDC with the upper and lower ranges.
Note: The emission reduction costs include the net cost changes due to changes of energy import and export.

This indicator considers the economy's capability of emission reductions.

Marginal abatement costs estimations across models (RITE DNE21+, FEEM WITCH and NIES AIM)



Source: B. Pizer, J. Aldy, R. Kopp, K. Akimoto, F. Sano, M. Tavoni, COP21 side-event; MILES project report for Japan

- The marginal abatement costs vary across models for some countries, but can be comparable for many countries/regions.
- The CO_2 marginal abatement costs of the NDCs of OECD countries are much higher than the marginal cost for the case that the aggregated NDCs are achieved most cost-efficiently (globally uniform marginal abatement cost).

Consideration of country's political and social situations in evaluation of the cost metrics

Cost metrics are comprehensive and good indicators for measuring emission reduction efforts, but …

- **How should we estimate the emission reduction costs more appropriately as the comparability metrics for measuring the efforts of NDCs?**

- **What are the inevitable social and political constraints for implementing climate policies?**

- **How should we treat the considerations of social and political constraints, e.g., nuclear power social acceptance, energy security issues, in the model analyses?**

More Detailed Analysis on Japan’s NDC

2030 Emission Target of Japan's NDC

Under the situations after the Great East Japan Earthquake and the Fukushima nuclear power accident, in 2014 the Japanese Government decided a new strategic energy plan which seeks a better balance of S+3E (safety, energy security, economy, and environment) and to reduce nuclear power plants. The energy mix for 2030 based on the strategic energy plan and the Japan's NDC which is consistent with the energy mix were decided in 2015.

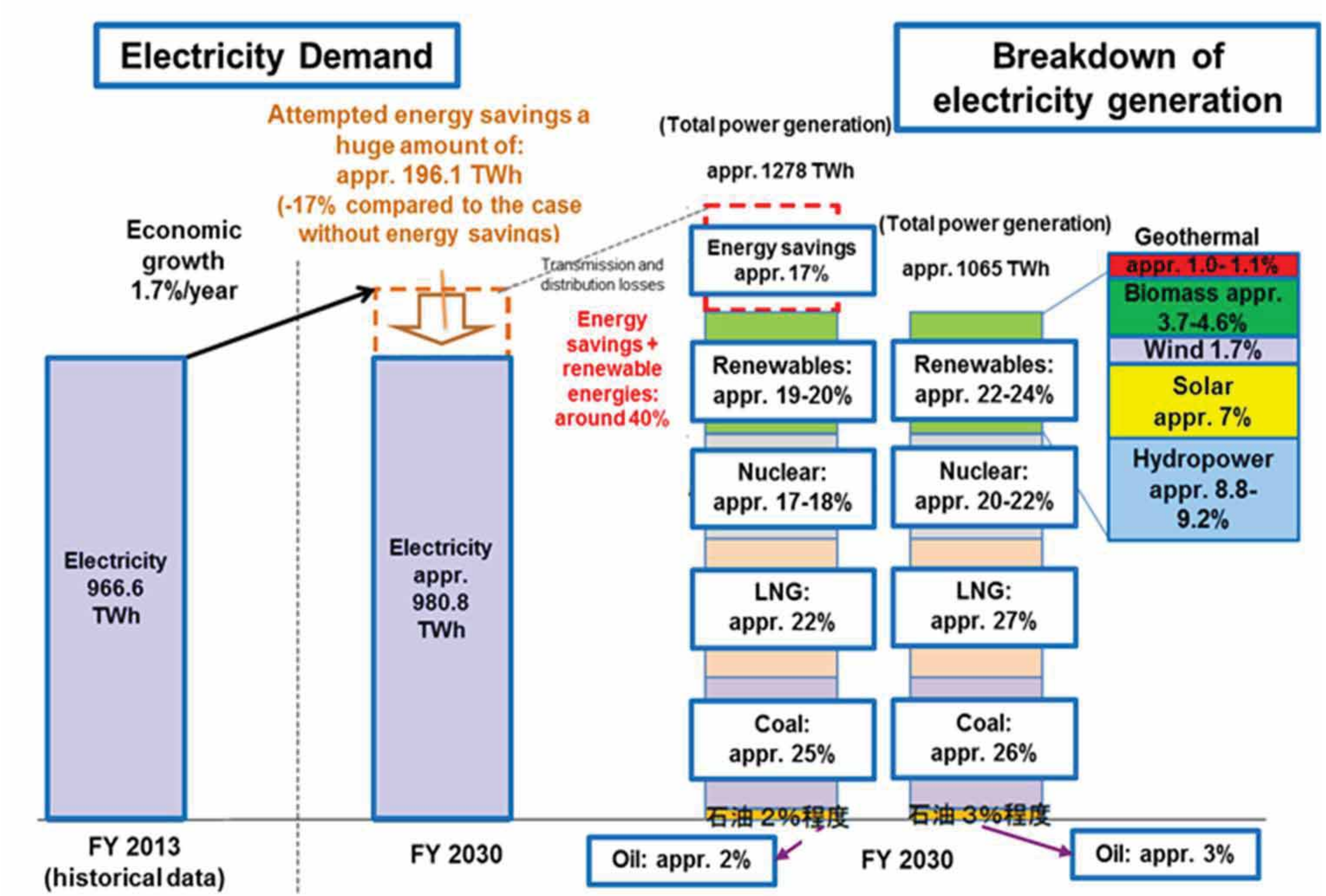
	2030; Compared to 2013（compared to 2005）
Energy-related CO_2	**-21.9%　（-20.9%）**
Other GHGs	-1.5%　（-1.8%）
Reduction by absorption	-2.6%　（-2.6%）
Total GHGs	**-26.0%　（-25.4%）**

Energy-related CO_2 by sector

	2005	2013	2030
Industry	457	429	**401**
Commercial and other	239	279	**168**
Residential	180	201	**122**
Transport	240	225	**163**
Energy conversion	104	101	**73**
Energy-related CO2 Total	1219	1235	**927**

Unit: Mt-CO_2

Japan's energy mix in 2030
– Electricity mix –



The Japanese government, July 2015

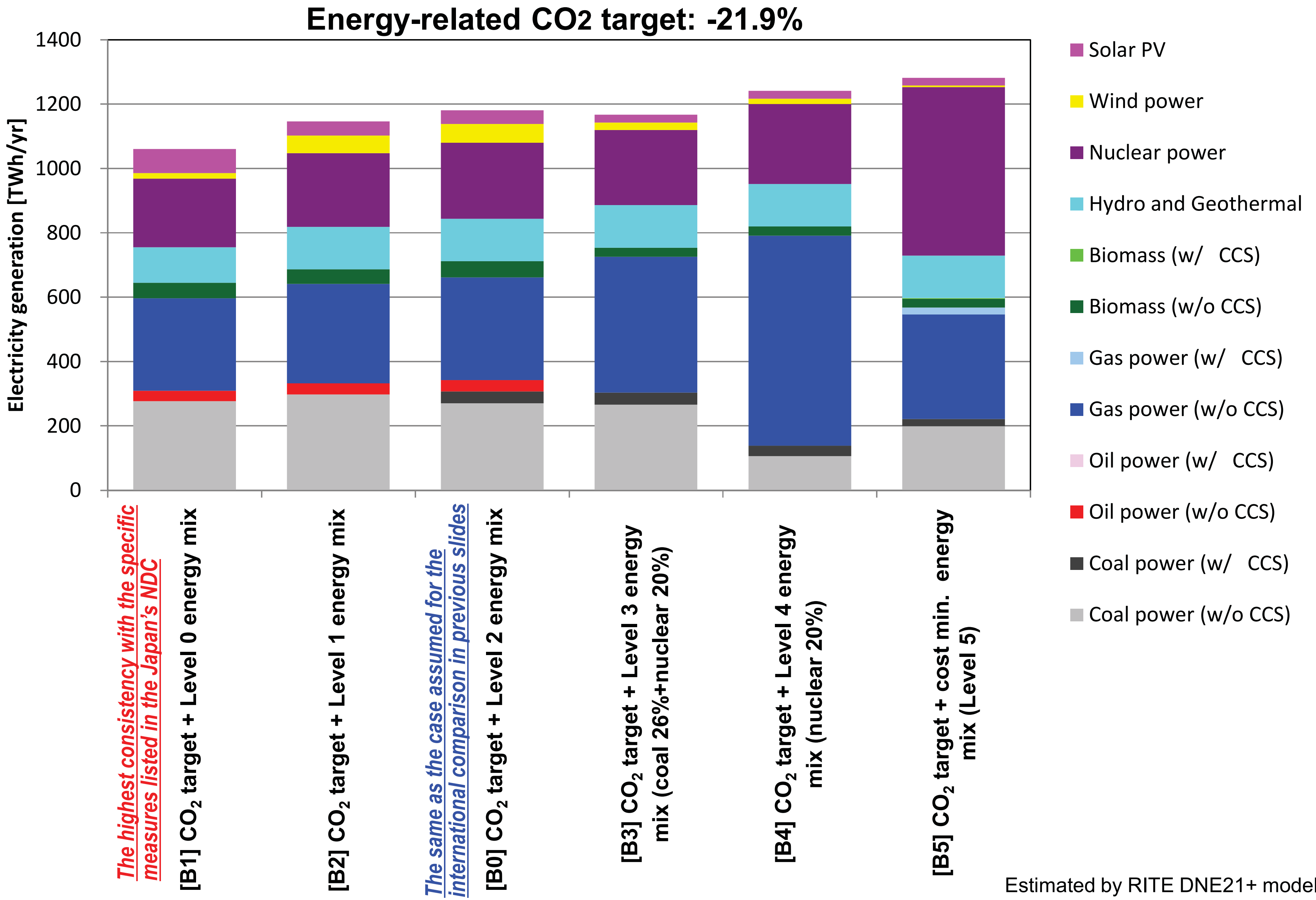
The government intends to reduce the dependence on nuclear power as compared with that before the accident. However, the government had to also take the 3E: energy security, economic efficiency, environment into account, and consequently the share of nuclear power is decided to be 20-22% of total electricity in 2030. I believe that this maintains a good balance of electricity mix in Japan.

The analysis cases for Japan's NDC

	GHG emis. target	Energy related CO2 emission target	Electricity share			w./w.o. CCS option	Electricity saving
			Fossil fuel	Nuclear power	Renewables		
[A0] GHG target + Level 2 energy mix [A] *(The same as the case assumed for the international comparison in previous slides)*	-26%	Cost min.	Coal: 26% LNG: 27% Oil: 3%	20%	24% (cost min. within renewable sources)	Cost min.	Cost min.
[B0] CO_2 target + Level 2 energy mix	-	[B] -21.9%	Coal: 26% LNG: 27% Oil: 3%	20%	24% (cost min. within renewable sources)	Cost min.	Cost min.
[B1] CO_2 target + Level 0 energy mix *(The highest consistency with the specific measures listed in the Japan's NDC)*	-	-21.9%	Coal: 26% LNG: 27% Oil: 3%	20%	24% (PV: 7%, wind: 1.7% etc.)	w.o. CCS	Total elec. Supply: 1065 TWh/yr
[B2] CO_2 target + Level 1 energy mix	-	-21.9%	Coal: 26% LNG: 27% Oil: 3%	20%	24% (cost min. within renewable sources)	w.o. CCS	Cost min.
[B3] CO_2 target + Level 3 energy mix (coal 26% + nuclear 20%)	-	-21.9%	Coal: 26% LNG: cost min. Oil: cost min.	20%	Cost min.	Cost min.	Cost min.
[B4] CO_2 target + Level 4 energy mix (nuclear 20%)	-	-21.9%	Cost min.	20%	Cost min.	Cost min.	Cost min.
[B5] CO_2 target + cost min. energy mix (Level 5)	-	-21.9%	Cost min.	Cost min.	Cost min.	Cost min.	Cost min.

Note: Higher level of energy mix provides more flexibility.

Evaluations of Japan's NDC in Electricity in 2030



Estimated by RITE DNE21+ model

Evaluations of Japan's NDC in Mitigation Cost in 2030

Estimated by RITE DNE21+ model

	Marginal abatement cost of CO2 ($2000/tCO2)	Mitigation cost increase (billion $2000/yr)	Mitigation cost increase per reference GDP (%)
[A0] GHG target (-26%) + Level 2 energy mix *The same as the case assumed for the international comparison in previous slides*	378	99	1.41
[B0] CO_2 target (-21.9%) + Level 2 energy mix	227	28	0.40
[B1] CO_2 target (-21.9%) + Level 0 energy mix *The highest consistency with the listed specific measures in the Japan's NDC*	242	38	0.55
[B2] CO_2 target (-21.9%) + Level 1 energy mix	272	32	0.46
[B3] CO_2 target (-21.9%) + Level 3 energy mix (coal 26% + nuclear 20%)	277	24	0.34
[B4] CO_2 target (-21.9%) + Level 4 energy mix (nuclear 20%)	165	20	0.28
[B5] CO_2 target (-21.9%) + cost min. energy mix (Level 5)	50	10	0.15

A0 → B0: 4.1% GHG reductions by non-energy CO2 is much more expensive than 21.9% GHG reductions by energy related CO2

B0–B5: Energy-related CO2 target (-21.9%)

B0 → B1: Electricity saving target etc.

B3 → B2: Renewable energy target etc.

B4 → B3: Considering energy security issue

B5 → B4: Considering social constraint of nuclear power

Note: it should be noted that the orders of between marginal cost and mitigation cost are different. The constraints for specific measures could reduce the CO2 marginal abatement cost while total mitigation cost increases.

Which constraints should we consider as appropriate?

Sensitivity to the mitigation measure options
(For energy-related CO_2 target (-21.9%) case)

RITE Research Institute of Innovative Technology for the Earth

Mitigation cost increase per reference GDP (%)

With CCS (≥Level 2 energy mix)	Without CCS (Level 1 energy mix)	Without CCS + Electricity savings (Level 0 energy mix)
0.44	0.49	**[B1] CO2 target + Level 0 energy mix** **0.55**
[B0] CO2 target + Level 2 energy mix **0.40**	**[B2] CO2 target + Level 1 energy mix** **0.46**	0.52
[B3] CO2 target + Level 3 energy mix (coal 26% + nuclear 20%) **0.34**	0.40	0.46
[B4] CO2 target + Level 4 energy mix (nuclear 20%) **0.28**	0.31	0.45
[B5] CO2 target + cost min. energy mix (Level 5) **0.15**	0.15	0.35

The same as the case assumed for the international comparison in previous slides ([B0])

The highest consistency with the listed specific measures in the Japan's NDC ([B1])

Arrows between the rows of the "With CCS" column:
- More specific renewable energy target
- Renewable energy target
- Considering energy security issue
- Considering social constraint of nuclear power

→ Larger constraints of mitigation measures of CCS and electricity savings

↑ Larger constraints of energy mix for renewables, fossil fuel, and nuclear power

Estimated by RITE DNE21+ model

More Detailed Analysis on the U.S.'s NDC

Consideration of Clean Power Plan (CPP)

- The U.S. submitted 26-28% reduction of GHG in 2025 relative to 2005 as her NDC.
- The U.S. will achieve the target by introducing domestic climate policies including the Clean Power Plan (CPP).

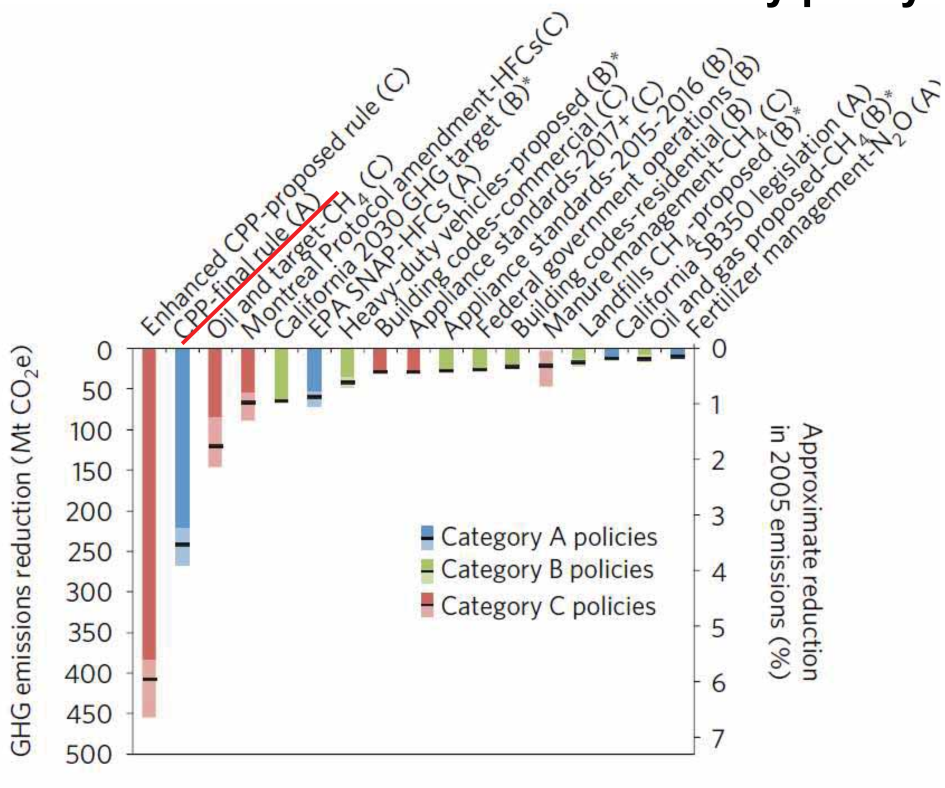
How does the CPP affect the emission reduction costs?

Assessment of the emission reduction effect of CPP by the U.S. EPA (million tCO2/yr)

	2020	2025	2030
Rate-based approach	69	232	415
Mass-based approach	82	264	413

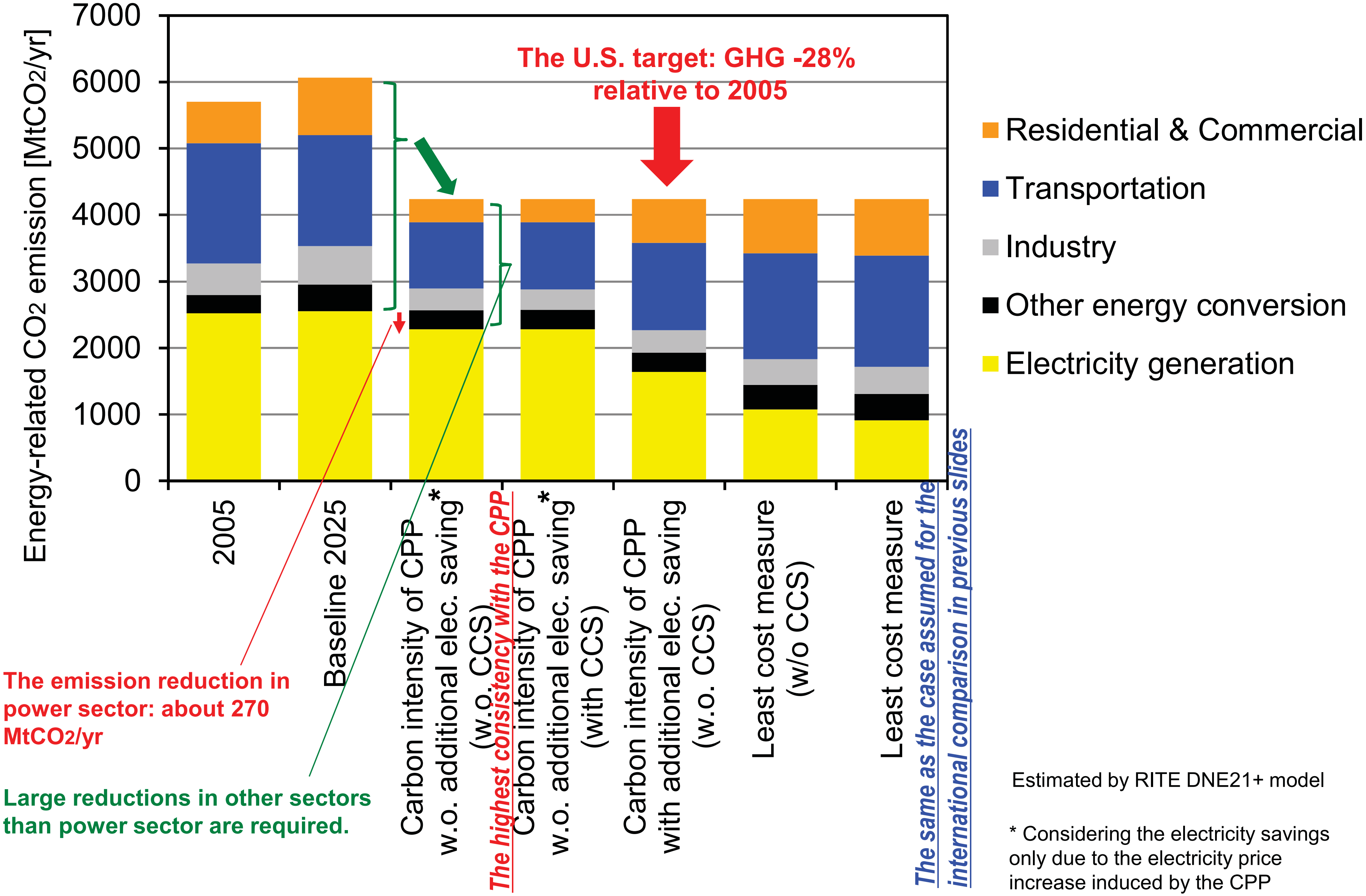
Source: US EPA, 2015

GHG emission reduction estimates by policy



Source: J.B. Greenblatt and M. Wei, Nature Climate Change, 2016

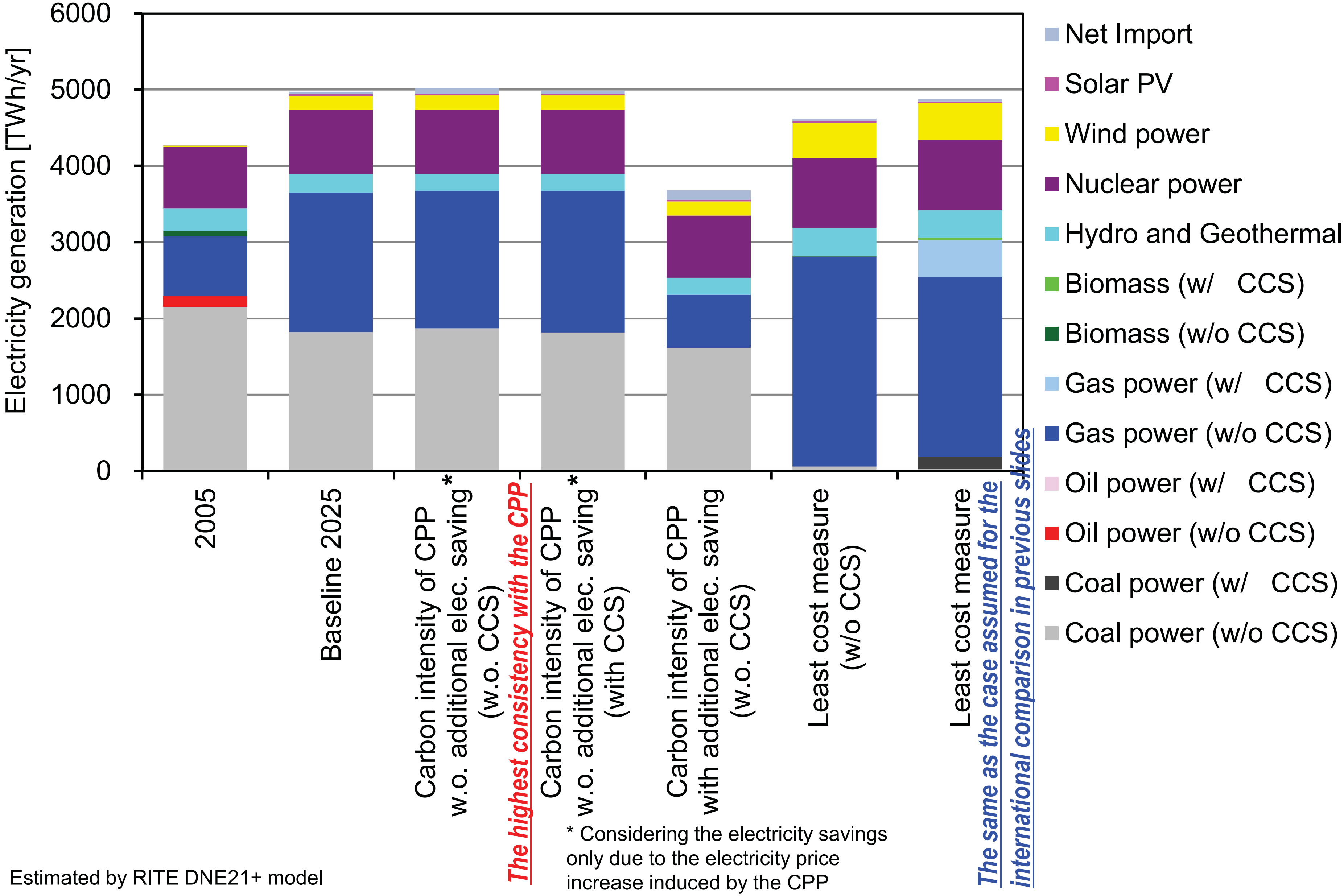
CO_2 emissions by sector in 2025 (-28% case)



Estimated by RITE DNE21+ model

* Considering the electricity savings only due to the electricity price increase induced by the CPP

Electricity generation in 2025 (-28% case)



* Considering the electricity savings only due to the electricity price increase induced by the CPP

Estimated by RITE DNE21+ model

Evaluations of the U.S.'s NDC in Mitigation Cost in 2025

Estimated by RITE DNE21+ model

GHG target (%)		Marginal abatement cost of CO2 ($2000/tCO2)	Mitigation cost increase (billion $2000/yr)	Mitigation cost increase per reference GDP (%)
-28%	[A1] Carbon intensity of CPP (w.o. CCS) w.o. additional elec. saving	**605**	**545**	**3.16**
	[A2] Carbon intensity of CPP (with CCS) w.o. additional elec. saving	**558**	**520**	**3.02**
	[A3] Carbon intensity of CPP with additional elec. saving	379	301	1.75
	[A4] The least cost measures (but w.o. CCS)	134	90	0.52
	[A5] The least cost measures	**94**	**65**	**0.37**
-26%	[B1] Carbon intensity of CPP (w.o. CCS) w.o. additional elec. saving	427	426	2.47
	[B5] The least cost measures	76	56	0.33

The highest consistency with the CPP (A1, A2)

The same as the case assumed for the international comparison in previous slides (A5)

- If the mitigation measures of power sector under the Clean Power Plan (CPP) are imperative, the mitigation costs are extremely large for achieving the 28% reduction relative to 2005 because large emission reductions are required in other sectors than power sector.
- There are large gaps in mitigation costs between the least cost measures and the realistic policy measures.

Conclusions

- **Measuring the 'emission reduction efforts (degree of ambition)' of NDCs is key for effective emission reductions under the Paris Agreement.**
- **Measuring the efforts is a hard work but can be approached by employing multiple good indicators including the mitigation costs.**
- **Evaluations of the mitigation costs require comprehensive models and include uncertainties but using several models helps ensure comparability to some extent.**
- **Another challenging issue on evaluations of the mitigation costs is what constraints are inevitable and should be considered in estimating the mitigation costs.**
- **Several social and political conditions hindering the least cost mitigation measures exist in each nation. Cheaper emission reduction measures should be pursued, but some of the realistic constraints should also be considered.**
- **At least, we should recognize the existence of such conditions that may cause cost increase for each nation in the review process of NDCs for effective emission reductions.**

Appendix

Assumptions of Population and GDP for the Estimations of the Indicators and Overview of the Models for the Estimations of Costs

Population prospects (millions)

	2010	2020	2030
Japan	127	124	118
United States	312	340	364
EU28	507	515	515
Switzerland	8	8	8
Norway	5	6	6
Australia	22	25	27
New Zealand	4	5	5
Canada	34	37	40
Russia	144	139	132
China	1367	1445	1477
Korea	48	49	49
Mexico	118	128	135
Ukraine	46	44	41
Belarus	9	9	8
Kazakhstan	16	17	17
East Europe (Non-EU countries)	23	23	22
Thailand	66	70	72
India	1206	1357	1474
Turkey	72	80	86
South Africa	51	54	56
The World Total	***6916***	***7679***	***8308***

Source) RITE estimates based on the 2008 UN population prospects in the medium variants. For statistical values up to 2010, The UN World Population Prospects 2012 are used.

GDP Prospects (MER, %/yr)

	2010—2020	2020—2030
Japan	1.4	1.9
United States	2.6	2.0
EU28	1.2	1.3
Switzerland	1.4	1.2
Norway	1.8	1.6
Australia	2.7	1.8
New Zealand	2.4	1.6
Canada	2.1	1.7
Russia	4.3	6.3
China	7.7	5.6
Korea	3.0	1.9
Mexico	3.2	3.0
Ukraine	3.2	5.3
Belarus	3.2	3.4
Kazakhstan	5.4	5.0
East Europe (Non-EU countries)	2.2	3.8
Thailand	4.3	4.0
India	6.5	5.9
Turkey	4.0	2.8
South Africa	2.5	3.4
The World Average	***3.0***	***2.9***

Source) RITE estimates. Our estimates are not so different form USDOE/EIA International Energy Outlook and IEA World Energy Outlook. (In consideration of the differences between PPP and MER)

Overview of the RITE Model

DNE21+ Model

- Assessment model for energy-related CO2 emissions
- 54 regions in the world
- Bottom-up modeling (200-300 specific technologies are modeled)

LULUCF Model

- Assessment model for Land use (land area for food production, energy crops, and afforestation)
- CO2 emission from LULUCF
- 15-minute-grid model
- Crop productivity is estimated based on the GAEZ model

Non-Energy CO2 Emissions Scenario

- Projection module for non-energy CO2 emissions
- 54 regions in the world
- Estimates of sectoral non-energy CO2 emissions to be consistent with GDP and production activities

Non-CO2 GHG Assessment Model

- Assessment model for the five types of non-CO2 GHG emissios (CH4, N2O, HFCs, PFC, SF6)
- 54 regions in the world
- The methodology is similar to the USEPA assessment

Integrated Assessment Framework covers 6 GHGs emissions, emission reduction costs and potentials, and cost-effective mitigation measures/technologies

Global Warming Mitigation Assessment Model
(Dynamic New Earth 21+)

The emission reduction costs in this study were estimated by an energy and global warming mitigation measures DNE21+.

- Energy-related CO2 emission reduction costs can be estimated with consistency.
- Linear programming model (minimizing world energy system cost)
- Evaluation time period: 2000-2050
  Representative time points: 2000, 2005, 2010, 2015, 2020, 2025, 2030, 2040, 2050
- World divided into 54 regions
  Large area countries are further divided into 3-8 regions, and the world is divided into 77 regions.
- Interregional trade: coal, crude oil, natural gas, electricity, ethanol, hydrogen, and CO2
- Bottom-up modeling for technologies both in energy supply and demand sides (about 300 specific technologies are modeled.)
- Primary energy: coal, oil, natural gas, hydro, geothermal, wind, photovoltaics, biomass, nuclear power, and ocean energy
- End-use sector: bottom-up modeling for technologies in iron & steel, cement, paper & pulp, chemical, aluminum, and car, and some technologies in residential & commercial sectors, and top-down modelling for sectors without bottom-up modeling by using price elasticity

The detailed assessments by region and by sector are possible with consistency.

The assessments of DNE21+ model are referred in the IPCC AR5, and those have been referred also for the decision processes for climate change mitigation policy in Japanese government.

[Reviewed articles (selected)]

K. Akimoto et al.; Estimates of GHG emission reduction potential by country, sector, and cost, Energy Policy, 38–7, (2010)

K. Akimoto et al.; Assessment of the emission reduction target of halving CO2 emissions by 2050: macro-factors analysis and model analysis under newly developed socio-economic scenarios, Energy Strategy Reviews, 2, 3–4, (2014)

Evaluations of Emission Reduction Efforts for the INDCs Submitted by Governments

Evaluated INDCs (1/2)

The 119 INDCs submitted as of October 1st, 2015 were evaluated.
As of October 1st, 2015, 119 INDCs had been submitted, and representing about 88 per cent of global emissions in 2010.
Comprehensive evaluations of emission reduction efforts were only for 20 countries (see below) due to the limited regional resolution of the model.

	2020 (Cancun Agreements)	Post-2020 (INDCs)
United States	-17% compared to 2005	-26% to -28% by 2025 compared to 2005
Canada	-17% compared to 2005	-30% by 2030 compared to 2005
EU28	-20% compared to 1990	-40% by 2030 compared to 1990
Switzerland	-20% compared to 1990	-50% by 2030 compared to 1990 （-35% by 2025 compared to 1990）
Norway	-30% compared to 1990	-40% by 2030 compared to 1990
Japan	-3.8% compared to 2005*	-26% by 2030 compared to 2013
Australia	-5% compared to 2000	-26% to -28% by 2030 compared to 2005
New Zealand	-5% compared to 1990	-30% by 2030 compared to 2005
Russia	-15 to -25% compared to 1990	-25% to -30% by 2030 compared to 1990

Note: More ambitious emission reduction targets had been submitted as “conditional “ targets from some countries, but they are not included in this table.
* Emission reduction target assuming zero nuclear power

Evaluated INDCs（2/2）

	2020 (Cancun Agreements)	Post-2020 (INDCs)
Non-EU Eastern Europe	—	-19% by 2030 compared to 1990*
Ukraine	-20% compared to 1990	-40% by 2030 compared to BAU
Belarus	-5 to -10% compared to 1990	-28% by 2030 compared to 1990
Kazakhstan	-15% compared to 1992	-15% by 2030 compared to 1990
Turkey	—	-21% by 2030 compared to BAU
Korea	-30% compared to BAU	-37% by 2030 compared to BAU
Mexico	-30% compared to BAU	-25% by 2030 compared to BAU** (-22% by 2030 compared to BAU in GHG)
South Africa	-34% compared to BAU	614MtCO_2eq/yr by 2030
Thailand	-7 to -20% compared to BAU (Energy and transportation sectors)	-20% by 2030 compared to BAU
China	To reduce CO_2/GDP by -40 to -45% compared to 2005	To reduce CO_2/GDP by -60 to -65% by 2030 compared to 2005 (To achieve the peaking of CO_2 emissions around 2030 and making best efforts to peak early)
India	To reduce GHG/GDP by -20 to -25% compared to 2005	To reduce GHG/GDP by -33 to -35% by 2030 compared to 2005

* The reduction rate was estimated from the total emissions by the INDCs of Albania, Makedonia, Moldova, and Serbia.

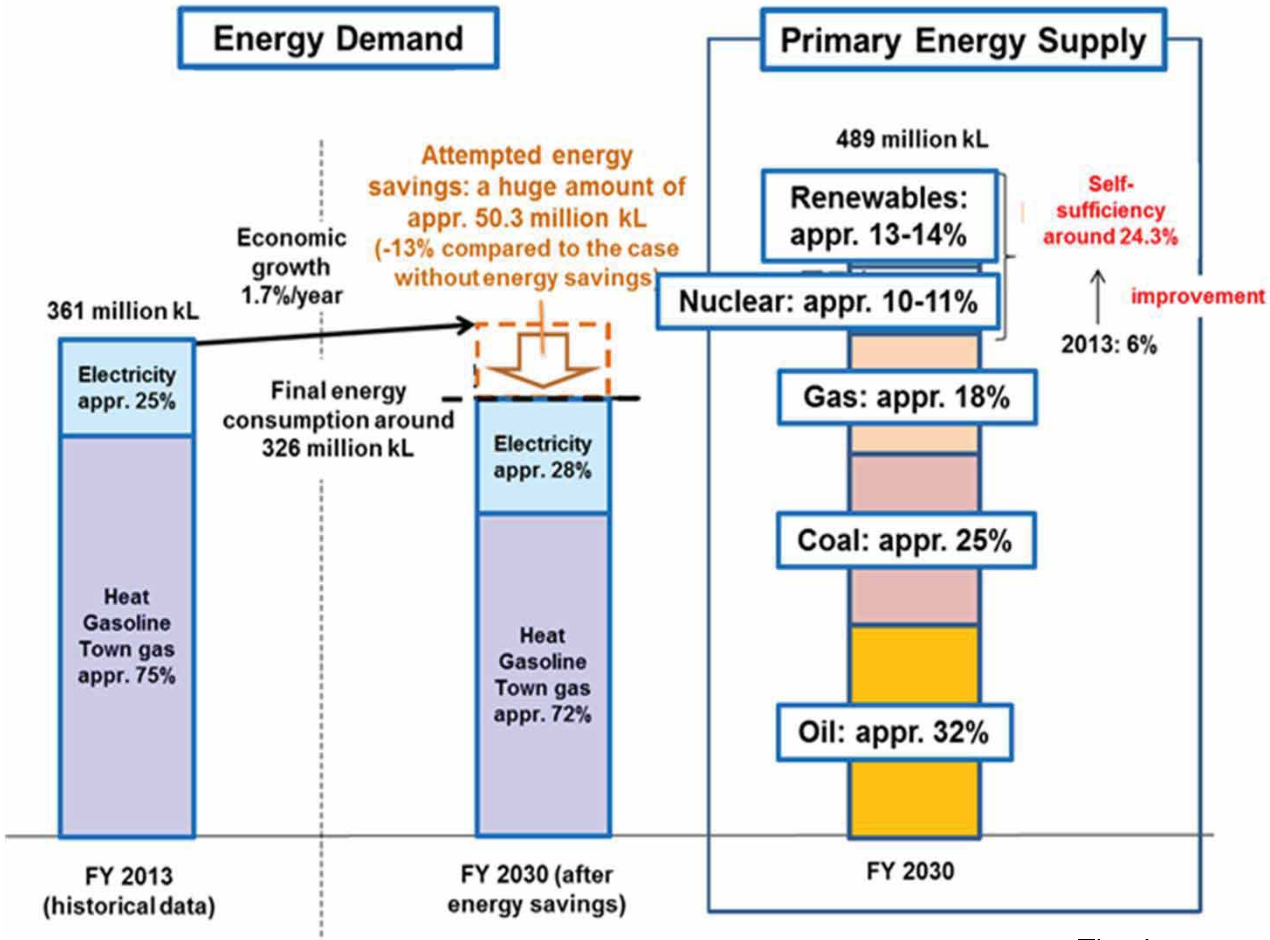
** Emission reduction target of Mexico includes black carbon.

Notes of the assessments of INDCs in this study

- LULUCF emissions are not taken into account for international comparison of mitigation efforts, because they have large uncertainty and their appropriate evaluation is difficult. (LULUCF emissions are taken into account for the aggregated INDCs evaluation with respect to 2°C target.)
- For the countries with emission reduction targets compared to the base year, the emissions in the target year are calculated based on historical emissions excluding LULUCF. Historical emissions are derived from Greenhouse Gas Inventory Office of Japan for Japan, UNFCCC for other Annex I countries, and IEA for other countries.
- For the countries with emission intensity improvements targets, the emissions in the target year are calculated based on historical emissions and our GDP scenario.
- For the countries with emission reduction ratio targets to BAU, if BAU emissions in target year are stated in their INDCs, the values of INDCs are adopted for calculation of emissions in the target year. If not, their INDCs are not evaluated in the international comparison of mitigation efforts in this study. (For the aggregated INDCs evaluation with respect to 2°C target, their carbon prices are assumed to be zero until 2030.)
- Other countries with policies and actions targets are omitted from this assessment.
- Most of the countries set 2030 as the target year, but the United States and Brazil chose 2025. For these countries, indicators concerning emission reduction efforts in 2025 are evaluated and compared with the other countries' indicators in 2030.
- Evaluation of all of the adopted indicators was carried out for twenty regions.
- For Brazil and Indonesia who are large emitters from LULUCF, only the three indicators (emission reductions compared to base year, emissions per capita, and emissions per GDP) are evaluated including LULUCF.

Japan’s Energy Mix in 2030

Japan's energy mix in 2030 – final energy and primary energy mix –



The Japanese government, July 2015

The energy mix was designed with the following three major objectives, plus the basic requirement of safety: 1) The self-energy sufficiency ratio should be required to be the same level as one before the earthquake (around 25%). 2) The electricity cost should be reduced compared to the current level. 3) Greenhouse gas emissions should be reduced as to make Japan a leading example for the rest of the world and the reduction efforts should be well compared with the EU's and the US's.